Graded lab assignment: Elevator controller

1 Overview

The NuSMV model for this exercise describes an elevator that can serve three floors. The model includes the physical system (buttons, cabin, door), and the controller. The goal of this exercise is to

1. complete the model by formalizing the transition relations,
2. formalize the given properties as temporal-logic properties, and
3. ensure that the requirements are satisfied.

The base model has to be complete and correct for passing. Furthermore, you are not allowed to make additional assumptions about the initial state of physical components (in particular, the starting floor and door state) if they are not already given by the model template. If your model passes all mandatory features, you can implement optional advanced features for a higher grade.

Note: For the basic features, no fairness conditions are allowed. For some advanced properties, fairness conditions are permitted if stated.

2 Base features (required for P)

2.1 Buttons

There is one button for each floor to request the elevator. Each button can be pressed non-deterministically. A pressed button stays active until the controller resets it.

2.2 Cabin

The cabin can be at any floor between 1 and 3. The controller decides the direction, which the engine translates into moving up or down, or stopping.

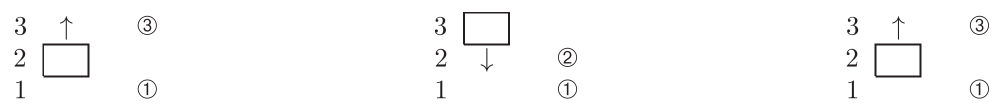
2.3 Door

The cabin is equipped with a door that can either be open or closed. The door responds to commands "open", "close", and "nop", which cause it to open, close, or stay in its current state.

2.4 Controller

The controller causes the cabin to move, the door to open or close, and resets the corresponding button when the elevator has served a request. It takes as input (sensor data) the current floor, the status of the door, the direction in which the cabin is moving, and the status of all buttons.

When you write the controller, be careful that you do not end up with cases where the elevator "bounces" between, for example, floors 2 and 3, even though there is also a request on floor 1 active (see Figure 1 for an example). To avoid this, you are not allowed to use fairness constraints.



(a) Elevator stops at floor 3. (b) Elevator stops at floor 2. (c) Elevator goes back to floor 3.

Figure 1: An example where the elevator ends up alternating endlessly between floors 2 and 3.

2.5 Safety/liveness properties

The following properties have to be specified in temporal logic:

1. The controller must not reset a button that is not pressed.
2. The cabin can move up only if the floor is not N.
3. The cabin can move down only if the floor is not 1.
4. The controller can issue an open command only if the door is closed.
5. The controller can issue a close command only if the door is open.
6. No button can reach a state where it remains pressed forever.
7. No pressed button can be reset until the cabin stops at the corresponding floor and opens the door.
8. A button must be reset as soon as the cabin stops at the corresponding floor with the door open.
9. The cabin can move only when the door is closed.
10. If no button is pressed, the controller must issue no commands and the cabin must be stopped.

You are free to choose LTL or CTL.

3 Tasks for higher grades

Note: It is not necessary to implement all optional features in the *same* model. If you want to work on different features in parallel, you can create multiple models that each implement one or more optional features.

3.1 Door safety

The door contains a sensor, which is triggered if something obstructs the door and may physically prevent it from closing.

Modifications: Add a non-deterministic variable *sensor* to the controller. Other modifications in the controller may be needed to prevent endless loops between the sensor and the floor button being active repeatedly.

Property: The door never closes when the sensor is on.

Fairness: The sensor is never tripped indefinitely.

3.2 Earthquake safety

The elevator has a sensor that detects strong shaking. In that case, it stops immediately (at the next floor) and opens the doors as soon as the cabin has stopped. It also deactivates all buttons and ignores any button presses. The elevator remains in that state until repair arrives.

An *earthquake* is a non-deterministic event. The corresponding state of the elevator remains set until another input, *repair,* is true. Repair can only reset the elevator state if the door is open. If the elevator door is open and an earthquake happens, repair cannot appear concurrently with the onset of the earthquake.

Modifications: Add variables *earthquake* and *repair* to the controller. You have to modify the logics of the controller, and possibly other modules, to implement the functionality described above.

Properties:

1. Modify existing properties to allow the controller to reset buttons in case of an earthquake.
2. When an earthquake happens...
   (a) The elevator stops in the next step.
   (b) The doors open within a few model transitions. You can use LTL operator `F[min, max]` for this.
   (c) The elevator remains stopped until repair arrives.

Fairness: Repair eventually arrives.

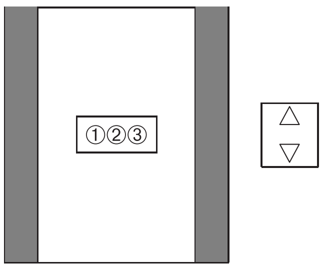
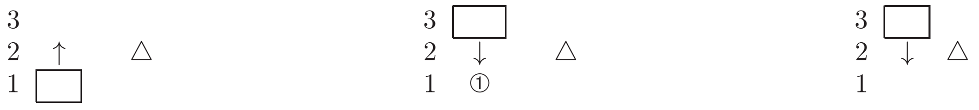


Figure 2: A schematic showing the elevator with open doors, and buttons inside and outside the cabin.



(a) Elevator stops at floor 2. (b) Elevator skips floor 2. (c) Elevator stops at floor 2.

Figure 3: Three scenarios with *p_2_up* pressed: elevator moving up; elevator moving down with an active request on floor 1; elevator moving down with no other requests active.

3.3 Directional buttons

The initial model is a very simple elevator with just one button (○) to stop the elevator whenever it arrives at a given floor. This causes the issue that someone in the second floor may want to return to the first floor, but ends up stopping the elevator when going up, so the elevator stops for no purpose.

In modern elevators, floors in the middle have two buttons, up (△) and down (▽), to ensure the elevator only stops when going in the right direction (see Figure 2). The lowest floor has only one button, up, and the top floor has only one button, down. These two edge cases work like a regular request button; the remainder of this section focuses on up/down buttons. In addition to that, there are still regular request buttons for each floor inside the elevator cabin.

An "up" button outside the cabin has the following semantics, shown in Figure 3:

1. When the elevator moves up, the button has the same effect as the button for that floor inside the elevator cabin. In other words, when the elevator moves up and arrives at the given floor, the elevator is expected to stop and open its doors (see Figure 3a). After that, the button is reset.

2. When the elevator moves down, the cabin passes (see Figure 3b) that floor unless there is no pending request at any lower floor (see Figure 3c). If there is no pending request further down, then the elevator stops at the given floor, opens the doors, and the request (button) is reset.

The "down" button works analogously.

Modifications: Add two more inputs, *p_2_up* and *p_2_down,* to the controller. Modify the controller to implement the functionality described above. It may be useful to have more "helper definitions" similar to *pending_X* to reduce the amount of code duplication.

Properties: Mandatory properties 7 and 8 need to be copied and adapted for the new buttons. Ensure that a directional floor button only gets reset when the elevator is going in the right direction, or when the cabin is about to change its direction! The final property also needs a minor modification.

3.4 Lobby mode

In some hotels, elevators are configured to return to the lobby (in this case, floor 1) when not used. Upon arrivals, the elevator doors open. Any request on any floor immediately overrides a return to the lobby.

Modifications: Implement the lobby mode by modifying the controller accordingly. You may also use additional definitions to minimize code duplication.

Property: The final property needs to be modified, as the elevator is no longer supposed to stop when no requests are active, but it is supposed to return to the first floor. This is a complex temporal property:

Description	Feature	Property	Points
The in-door sensor is implemented correctly, with a correct property and fairness condition (if needed).	easy	easy	+0.5
The earthquake sensor and repair reset are implemented correctly, with at least one correct safety property (if the property is incorrect, the property from our solution will be used to check the model).	medium	easy	+0.5
All properties related to the earthquake sensor are correct.		medium	+0.25
Directional buttons are implemented correctly, all old and new properties hold.	difficult	medium	+1.5
The lobby functionality is implemented correctly (if the property is incorrect, the property from our solution will be used to check the model).	easy		+0.25
The property (and, if needed, fairness condition) related to the lobby functionality is correct.		difficult	+0.5
Documented error trace of incorrect model.	easy		+0.25
Documented error trace of incorrect property.		easy	+0.25

Table 1: Extra points for advanced features/properties.

As long as no requests are active, the elevator is supposed to return (eventually) to the first floor and open its doors.

Fairness: You may need fairness conditions to fulfill the property.

3.5 Validation, documentation

An extra half point can be obtained by validating and documenting the model. Commented error traces can be pasted and explained at the bottom of the submission, as a multi-line comment between `/--` and `--/`.

Optional: You document an example error trace with a faulty (older?) or mutated *model.* (+0.25)

Optional: You document an example error trace with a faulty (older?) or mutated *property.* (+0.25)

4 Grading criteria

Pass (E):

- The submitted work is your group's own original work. You may look at examples from the web for inspiration, but you are not allowed to copy code from the web. Note that the given model is a heavily modified version from an example you can find on the web.[1]
- All ten mandatory properties are correct.
- The model correctly implements all ten properties (no error traces found by NuSMV).
- No additional assumptions about the initial state of physical components are made.
- No fairness conditions are used for the mandatory properties and any variables in given the model template.

Extra points are awarded according to Table 1.

Reduced points for late submissions! The maximal number of points is reduced by 1 for each missed deadline. There are three deadlines: for the small lab exercises, for the peer review, and for this exercise.

[1]In the peer review, you will received advice on your model, but other groups shall not provide ready-made solutions to problems encountered in the initial version.